

§14. Two-dimensional Simulation Study on Charging of Dust Particle on Plasma-Facing Wall —Simulation Results—

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The PIC simulation code two-dimensional in space (r, z) and three-dimensional in velocity space (v_z, v_r, v_θ) has been developed for the simulations of a sheath with a dust particle¹⁾. The one-dimensional theoretical consideration of the dust particles behaviour on a plasma-facing wall [9] neglects the effect of the dust on the plasma that is necessary to solve analytically dust statics equations on the wall and obtain expressions for dependencies of the critical dust radii on local plasma parameters and the wall potential. However, the kinetic approach is necessary to describe the self-consistent interaction of the dust particle with the plasma as the dust charging and shielding depend on velocity distribution functions of plasma particles as well as affect them due to absorption and scattering processes.

In Fig.1 the potential distribution around the dust particle with $R_d / \lambda_D = 3.1$ on the wall with potential $e\phi_w / T_e = -5.0$ is shown. As can be seen, the sheath potential is disturbed significantly by the dust particle near the upstream dust side, while in the shadow region between the wall and the dust the potential is close to the wall potential and the plasma density is low. Along the parallel to the wall direction the disturbance of the potential extends on a few Debye lengths as one could expect. Therefore, the dust surface charge and the enhancing of the surface electric field by plasma is the strongest on the upstream side. With increasing of the dust radius the effect of the wall reduces and an individual sheath around the dust particle is formed due to plasma shielding. It leads to formation of the wall-independent electric field on the dust surface and saturation of the dust surface charge density. The distributions of the surface charge density for the dust particles of different radii and the wall potential $e\phi_w / T_e = -5.0$ are shown in Fig.2. The angle α in the figure is the angle between the z -axis and a dust radius-vector counted from the upstream point of the dust surface. As can be seen, the surface charge density profile is flatter for the big dust particle. With increasing of the dust radius the surface charge density near upstream point decreases due to reduction of the sheath electric field, while in a uniform external electric field it should have a fixed cosine profile. At the same time the dust surface charge density increases on the close to the wall dust side that indicates the formation of the individual dust sheath. Therefore, the plasma shielding effect leads to saturation of the dust surface charge density for the dust particles bigger than the Debye length at a different level than predicted by the 1D model. Thus, we can expect that for a smaller Debye length the charge of the dust particle with a fixed radius at the wall with a fixed potential is larger than that for a longer Debye length and, correspondingly, the repulsive electric force is stronger. The formation of an

individual sheath around dust particles, which radii are much bigger than the Debye length, cause saturation of the dust surface electric field and the corresponding surface charge density. The results of this work can help to extend the theory of dust release from a plasma-facing wall for the case of bigger than the Debye length dust particles.

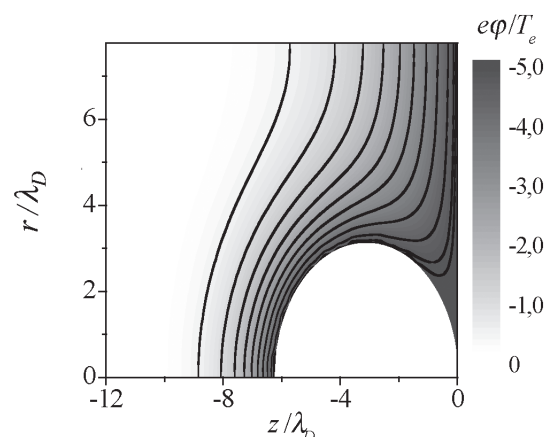


Fig. 1 Spatial distribution of the potential around the spherical dust particle of the radius $R_d / \lambda_D = 3.1$ on the plasma-facing wall with the potential $e\phi_w / T_e = -5.0$.

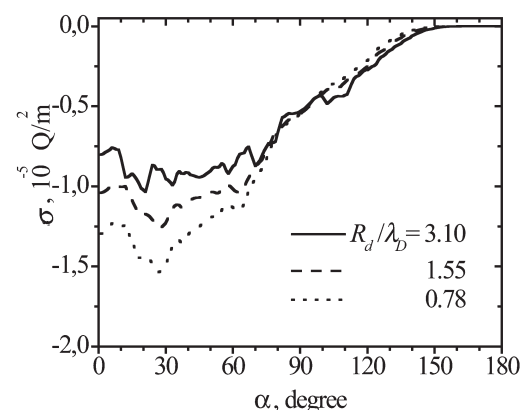


Fig. 2 Profiles of the surface charge density of the dust particles of different radii on the plasma-facing wall with the potential $e\phi_w / T_e = -5.0$.

Reference

- 1) Smirnov, R., Tomita, Y., Tskhakaya, D., Takizuka, T., Contrib. to Plasma Physics, **46** (2006) 623-627.